

Soil Moisture Experimental Plan for IPHEX-2014

(Essential Parts are adapted from previous experiment plan for SMEX02-05 and SMAPVEX12; Draft v0; Updated: May 4, 2014)



1. Introduction	3
2. Remote Sensing Instruments	4
3.1 Satellite-borne Sensors	4
3.1.1 The Soil Moisture Ocean Salinity (SMOS) mission	4
3.1.2 The Soil Moisture Active Passive (SMAP) mission	4
3.2 Airborne Scanning L-Band Active and Passive (SLAP)	4
3. Study Region and Sites	6
4. Field Measurements	12
4.1 General Guidance on Field Sampling	12
4.2 Soil Moisture, Soil Temperature and Surface Temperature	13
4.3 Theta Probe Soil Moisture Sampling and Processing	17
4.4 Gravimetric Soil Moisture Sampling with the Scoop/Spatula Tool	24
4.5 Gravimetric Soil Moisture Sample Processing	25
4.6 Soil Temperature Probes	26
4.7 Infrared Surface Temperature (IRT)	27
4.8 Soil Bulk Density Sampling with the Coring Tool	28
4.9 Surface Roughness	30
4.10 Vegetation Sampling	31
4.11 Global Positioning System (GPS) Coordinates	36
5. Schedule	41
6. Logistics	42
7. Volunteer List	51

1. Introduction

Ground validation campaigns before and after the launch of NASA's Global Precipitation Measurement Mission (GPM) Core satellite in early 2014 have been planned to collect targeted observations to support precipitation retrieval algorithm development, to improve the science of precipitation processes, and to demonstrate the utility of GPM data for operational hydrology and water resources applications. The Integrated Precipitation and Hydrology Experiment (IPHEX) centered in the Southern Appalachians and spanning into the Piedmont and Coastal Plain regions of North Carolina seeks to characterize warm season orographic precipitation regimes, and the relationship between precipitation regimes and hydrologic processes in regions of complex terrain. As part of the IPHEX2014 experiment, an additional opportunity to fly the SLAP (Scanning L-band Active Passive) instrument, an aircraft scale simulator of the instruments to fly in NASA's upcoming SMAP (Soil Moisture Active Passive) mission, to collect soil moisture measurements for ground validation has recently arisen. Soil samples will be collected concurrent with flight, and will be integrated with the long-term monitoring network and with IPHEX station measurements to develop a consistent ground-validation data set.

Research objectives of the soil moisture experiments include but not limit to:

- a. to assess and evaluate current satellite soil moisture products (i.e. SMOS, AMSR2, etc.) in moderately or densely vegetated region;
- b. to validate soil moisture retrieval algorithms combining passive and active brightness temperature for upcoming satellite mission (e.g. SMAP) using the SLAP observed brightness temperature;
- c. to investigate the potential to improve the estimation of surface soil moisture at regional scale by merging land surface hydrologic model and satellite observations;
- d. to investigate the potential to enhance hydrological forecast skills by assimilating soil moisture measurements into hydrological model.

2. Remote Sensing Instruments

3.1 Satellite-borne Sensors

3.1.1 The Soil Moisture Ocean Salinity (SMOS) mission

The SMOS (Soil Moisture and Ocean Salinity) satellite was launched on 2nd November 2009, is the first satellite to provide continuous multi-angular L-band (1.4GHz) radiometric measurements over the globe. Over continental surfaces, SMOS provides near-surface soil moisture data at ~50km resolution with a repeat cycle of 2-3 days. The payload is a 2D interferometer yielding a range of incidence angles from 0° to 55° at both V and H polarizations, and a 1,000km swath width. Its multi-incidence angle capability is expected to assist in determining ancillary data requirements such as vegetation attenuation. This satellite has a 6:00am/pm equator overpass time (6:00am local solar time at ascending node).

3.1.2 The Soil Moisture Active Passive (SMAP) mission

NASA's next generation soil moisture dedicated mission, Soil Moisture Active Passive ([SMAP](#)), will provide invaluable real-time soil moisture variability at high resolution through the synergy of L-band (1.4GHz) active (radar) and passive (radiometer) microwave observations. SMAP instrument is the first L-band combined active/passive mission, designed to make coincident measurements of surface emission and backscatter, with the ability to sense the soil conditions through moderate vegetation cover. The instrument measurements will be analyzed to yield estimates of soil moisture and freeze/thaw state. The measurement swath width is 1000 km, providing global coverage within 3 days at the equator and 2 days at boreal latitudes (>45 degrees N). SMAP launch is currently planned for October, 2014.

3.2 Airborne Scanning L-Band Active and Passive (SLAP)

SLAP (Scanning L-band Active Passive) instrument, an aircraft scale simulator of the instruments to fly in NASA's SMAP mission, will conduct measurements for ground validation. SLAP will fly on Langley's King Air aircraft.

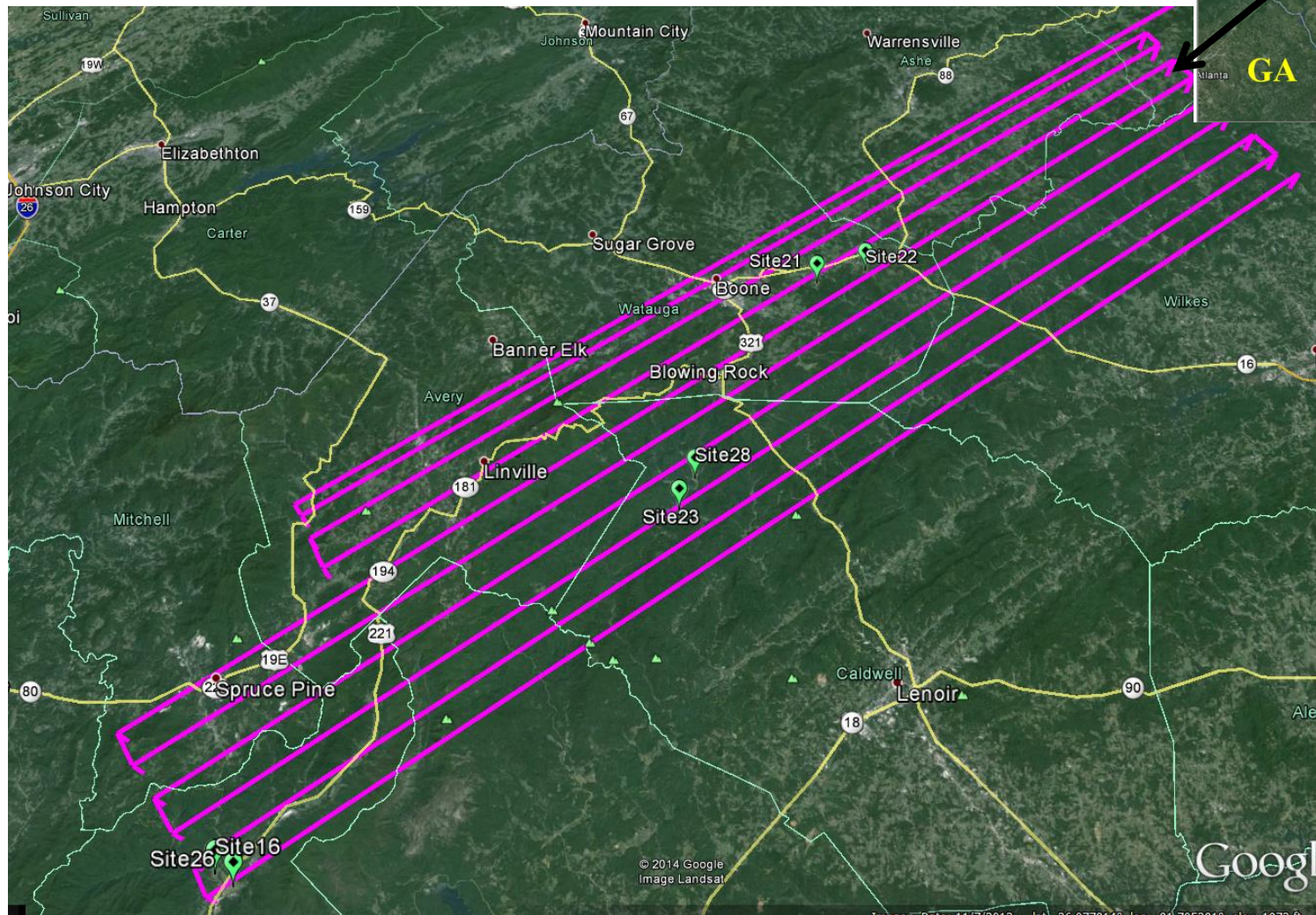
Parameter	Radiometer	Radar
Frequencies (GHz)	1.4	1.26
Polarization	V and H	VV, HH, VH, and HV
Sensitivity (K or dB)	tbd	tbd
Incidence angle (degree)	40	40
Spatial resolution (m) (at 6500 ft ASL)		
Swath Width (m)		

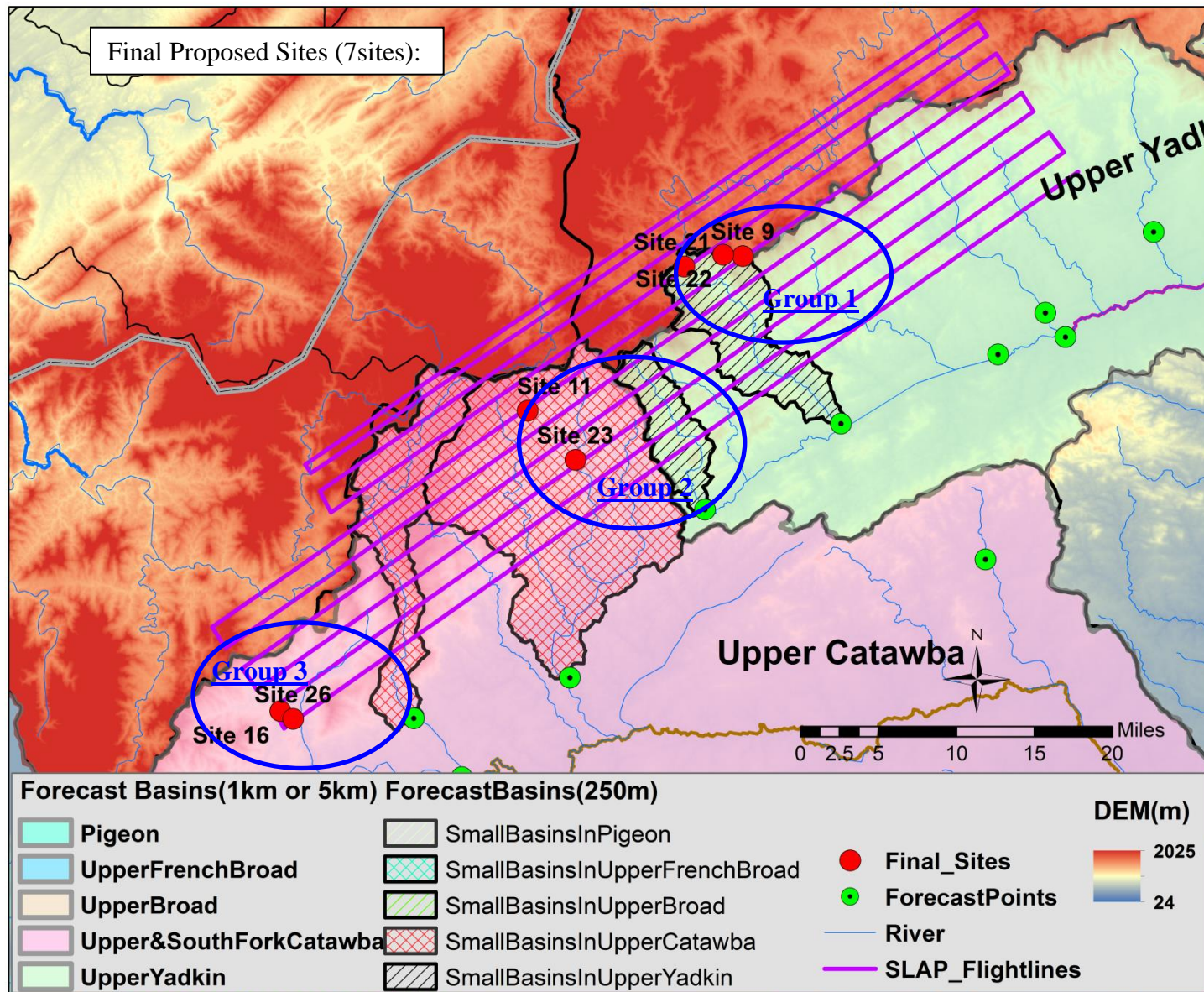
Flight lines:

Line No.	Altitude (km)	Length (km)	Start Lat.	Start Lon.	Stop Lat.	Stop Lon.
1		85	36.519333	-81.136833	36.029667	-82.017167
2		85	36.021833	-82.010333	36.445000	-81.247000
3		85	36.432667	-81.236667	36.005000	-82.000000
4		85	35.985333	-81.987000	36.416000	-81.225833
5		100	36.398000	-81.211167	35.877500	-82.121667
6		100	35.858167	-82.105833	36.379500	-81.196500
7		100	36.362333	-81.183000	35.839500	-82.086667
8		100	35.819833	-82.069667	36.343000	-81.164833
9		100	36.324333	-81.147833	35.802500	-82.051500
10		100	35.784000	-82.038167	36.306167	-81.131500

3. Study Region and Sites

The study region: pink lines indicate flight lines, sites are marked.

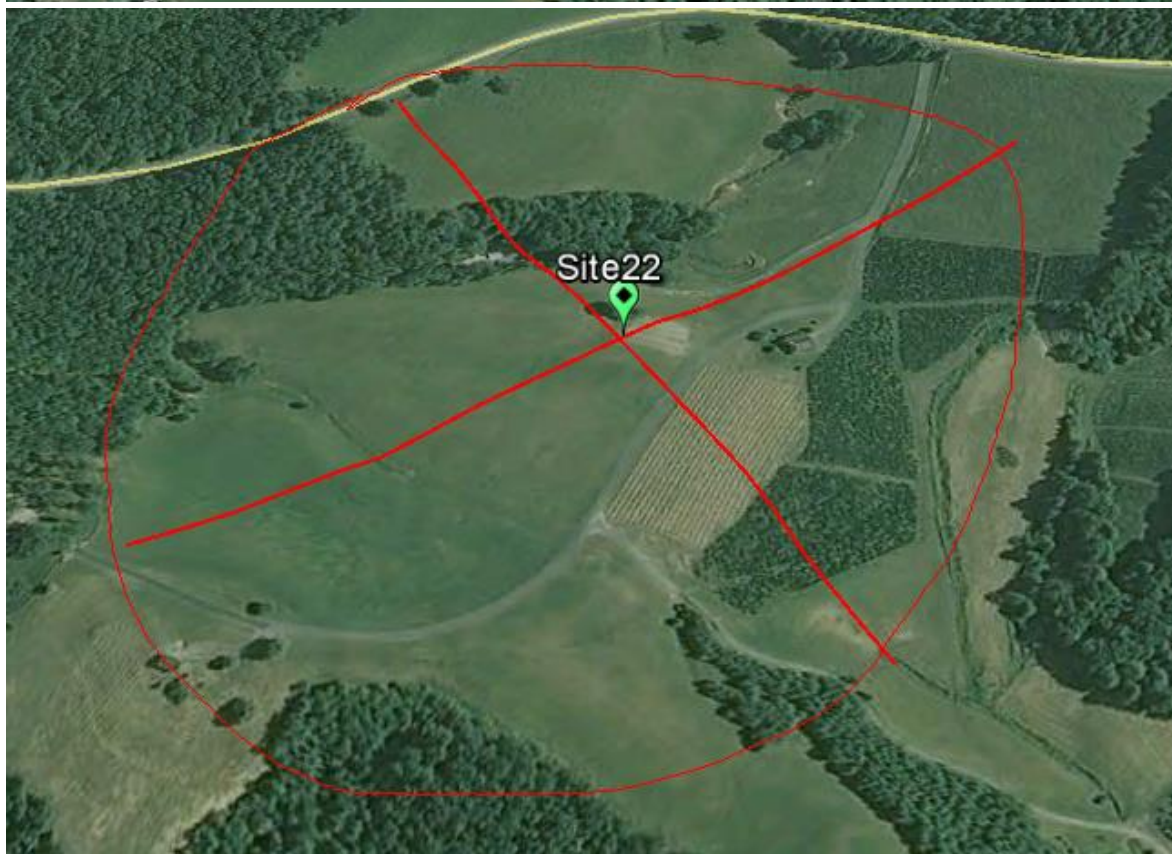




Final Soil Moisture Sites: (Ownership data was obtained from <https://www.lib.ncsu.edu/gis/counties.html>)

<u>Team</u>	<u>Sites No.</u>	<u>Description</u>	<u>Lat.</u>	<u>Lon.</u>	<u>Land Cover</u>	<u>County</u>	<u>Land Owner</u>	<u>Contact</u>	<u>Parcel ID</u>	<u>Permiss ion</u>
Group 1	Site 21	With isolated forest	36.216691	-81.583917	Grassland	Watauga	BROWN, ALVIN BLAKE	217 DANIEL DR BOONE, NC 28607	2930775749000	Yes
	Site 22	With some forest	36.230431	-81.547296	Cropland/Grassland	Watauga	CARROLL NC PROPERTIES, LLC	PO BOX 1549 BOONE, NC 28607 1549	2951101578000	Yes (veg)
Group 2	Site 28	Nursery	36.059375	-81.694500	Cropland	Caldwell	UPTON VALLEY NURSERY INC	6640 GLOBE RD LENOIR, NC 28645-7780 (828-758-0579)	02 4W1 9 8B	
	Site 23	Many different crops	36.036190	-81.707537	Cropland	Caldwell	GRAGG ROBERT GRAGG LARRY	6295 GLOBE RD LENOIR, NC 28645 Chad Cragg (828-496-7022)	02 4W111 9	Yes
Group 3	Site 16	Large cropland with isolated forest area	35.800076	-82.042432	Cropland	McDowell	BENFIELD JEFFERY	Benfield Nursery 43 Old Linville Rd Marion, NC 28752 Phone: 828 756-2262	79500583643	Yes
	Site 26	Many different crops	35.793058	-82.027969	Cropland	McDowell	BENFIELD JEFFERY	Benfield Nursery 43 Old Linville Rd Marion, NC 28752 Phone: 828 756-2262	170500275554; 170500173082	Yes

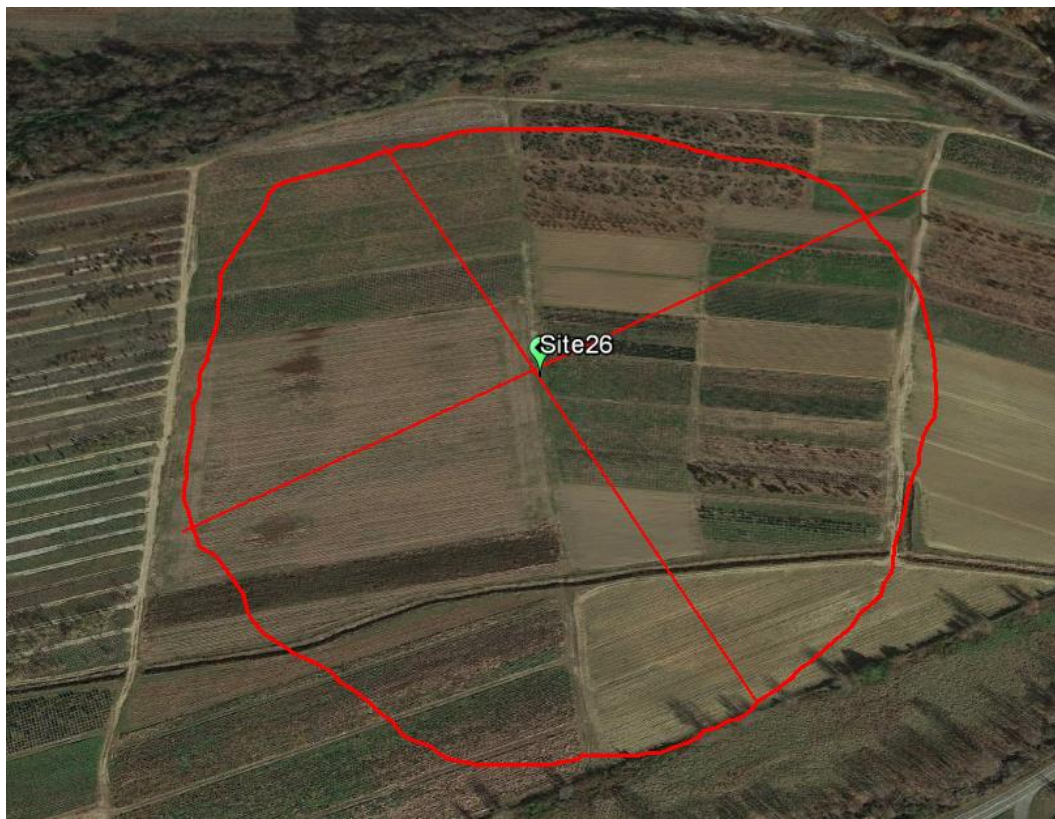
Group1: Site21, Site 22



Group 2: Site 11 and Site 23



Group 3: Site 16 and Site 26



4. Field Measurements

Sampling will be performed on irregular sites due to the topography. About 8~10 locations in each site will be sampled. The sampling will be conducted between 9:30 and 11:30 local time. The primary measurement was the 0-6 cm dielectric constant at a single location in each site using Theta Probes. The dielectric constant is converted to volumetric soil moisture using a calibration equation later. Volunteers will extract soil moisture samples of the 0-6 cm soil layers.

4.1 General Guidance on Field Sampling

- Sampling is conducted **only on flight dates**. It is canceled if it is raining, there are severe weather warnings or a logistic issue arises.
- **Know your pace**. This helps greatly in locating sample points and gives you something to do while walking.
- If anyone questions your presence, politely answer identifying yourself as a scientist working on a NASA/Duke soil moisture study with satellites. If you encounter any difficulties **just leave** and report the problem to the group leader.
- Although gravimetric and vegetation sampling are destructive, try to **minimize your impact** by filling holes. Leave nothing behind.
- Always sample or move through a field along the **row direction** to minimize impact on the canopy.
- Please be considerate of the landowners and our hosts. **Don't** block roads, gates, and driveways. Keep sites, labs and work areas clean of trash and dirt.
- Watch your **driving speed**, especially when entering towns. Be courteous on dirt and gravel roads, lower speed=less dust.
- **Close any gate** you open as soon as you pass.
- Work in **teams of two**. **Carry a cell phone**.
- Know where you are. All roads have street signs. Make a note of your closest intersection.
- Dress correctly; long pants, long sleeves, waterproof boots
- Contact with some vegetation might cause a skin irritation

4.2 Soil Moisture, Soil Temperature and Surface Temperature

Ground sampling will take place between 9:30 am and 11:30 am.

Soil moisture and temperature sampling is intended to estimate the site average and standard deviation values at the scale of passive microwave (radiometer) footprints (~400m×600m). The variables that will be measured or characterized are:

- 0-6 cm soil moisture using the Theta Probe (TP) instrument
- 0-6 cm gravimetric soil moistures using the scoop/spatula tool
- 0-6 cm soil bulk density (separate trip, not included in the regular trip)
- Surface temperature using a hand held infrared thermometer
- 1 cm soil temperature
- 5 cm soil temperature
- 10 cm soil temperature
- GPS locations of all sample point locations

Preparation

- Check in with group leader and confirm the flight.
- Assemble sampling kit
 - Bin box
 - Theta Probe and data logger (use the same probe each time, it will have an ID)
 - 8 cm spatula
 - 4 cm spatula
 - Notebook/ Data sheet
 - Pens
 - Cans
 - Soil thermometer probe
 - Handheld infrared thermometer (IRT)
 - Brush
 - Extra batteries (9v, AA, AAA)
 - First aid kit (per car)
 - Phone & Camera
- For each site, each team should take 4~5 cans. The cans were already labeled, be sure to record the letter or number on data sheet.
- Verify that your TP, data logger, infrared instrument, and soil thermometer are working.
- The first time you sample, it will help to use flags to mark your transect rows and sample point locations.
- All sample points should be located with a GPS once during the experiment. Points will be saved as XX-YY. XX is your site ID and YY is your sampling point ID

- Use a new **datasheet** page for each site. Take the time to draw a good map and be legible. Return to group leader after each trip.

Procedure

- Upon arrival at a site, note site id, your name(s) and time in datasheet. Draw a schematic of the field (It might be a good idea to do this before you go out for the day). Make some notes about your site, the vegetation type, the wet/dry condition, how flat the area is. Take a picture of the field if you can.
- From a corner of the site, measure 100 m along one side to locate the first transect.
 - Transects should be parallel with the row direction, if there is. If not, should follow the direction of flights.
 - If possible, select a row that is a tractor row to walk in.
- From this location initiate a sampling transect across the site. Take the first sample at 100 m and repeat every 100 m until you are 100 m from the edge of the site. It will result in 4~5 samples along one transect.
 - Sample in the row adjacent to the row you are working in, it is suggested that this be the row to your right.
 - At all points collect **three** TP samples across the row as suggested in Figure 7.
 - At all points, measure the soil temperature at 1cm, 5cm and 10 cm depths using the digital thermometer provided. Record these values in degrees C to one decimal point in the field notebooks at the point location on the map.
 - At all points, measure the surface temperature. Record these values in degrees C to one decimal point in the field notebooks at the point location on the map.
 - At specific points shown in Figure 6 (**four** per site) collect a gravimetric soil moisture (GSM) sample for 0-6 cm following the procedures described using the scoop/spatula, enter the letter/numbers labeled on cans on datasheet.
- After completing this transect move about 250 m perpendicular into the site and initiate a new transect. This will result in a total of 8~10 sampling points.
- As you move along the transect note any anomalous conditions on the schematic in your datasheet, i.e. standing water.
- Record your stop time and place cans in box. Try to keep them cool.
- Clean all the tools before putting them back into the box.

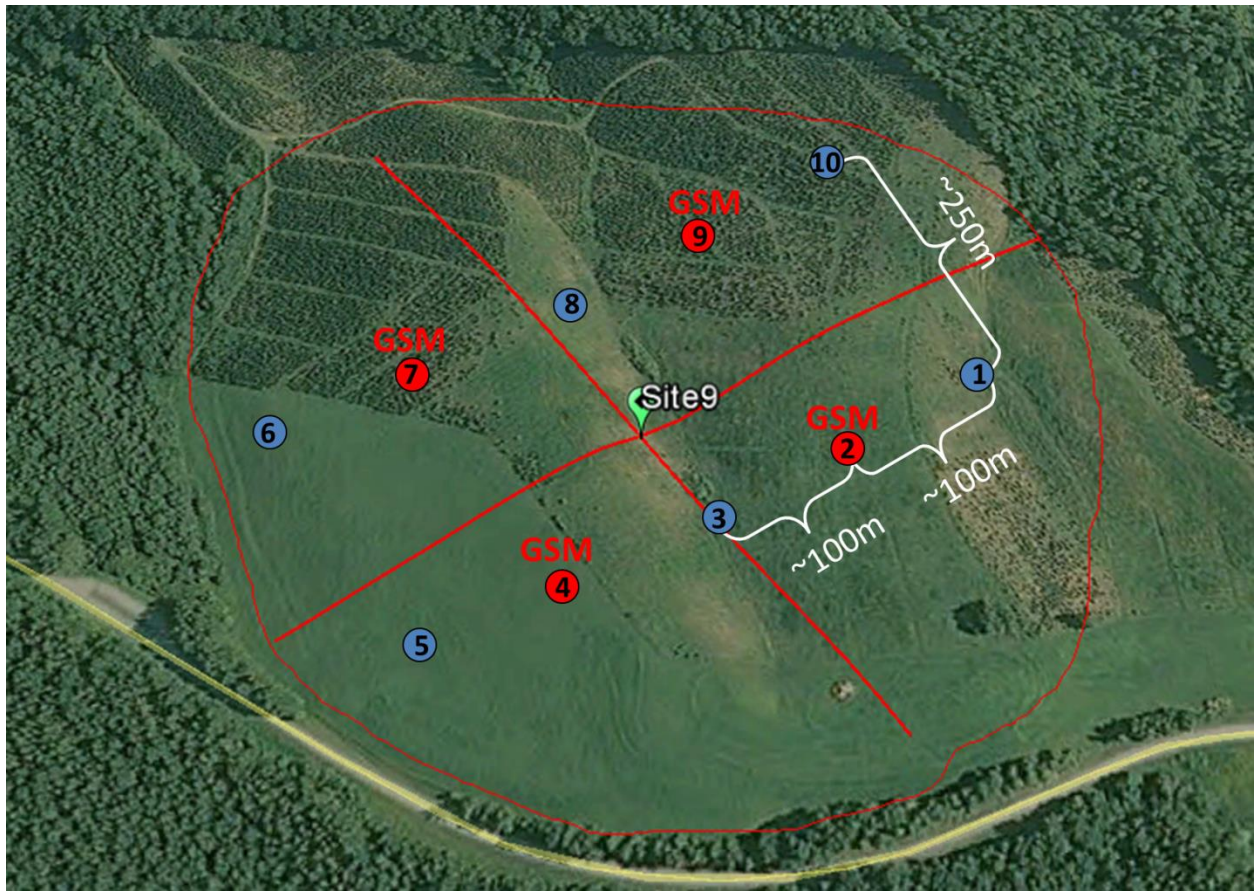


Figure 6. Schematic of layout of samples in a watershed site.

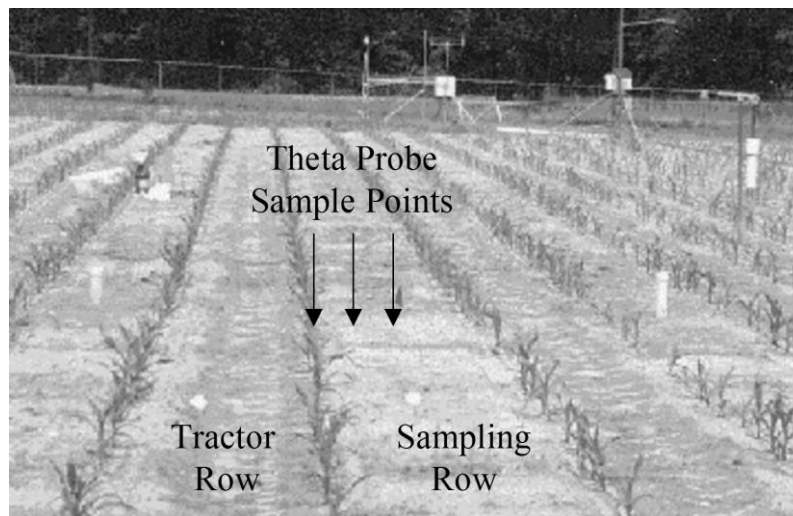
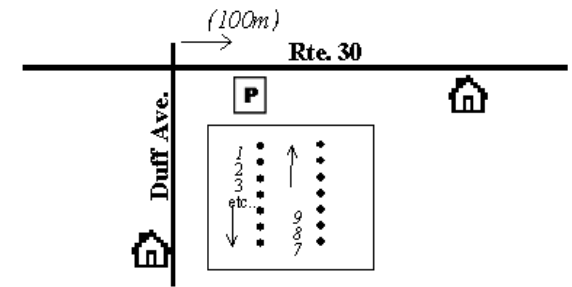


Figure 7. Schematic of layout of Theta Probe sample points.

Example:

Date: May 2
 Site: Site 23
 Start: 9am
 Stop: 11:30am
 Team: Jing and Tan

Notes: Field conditions wet today, heavy storm yesterday.



Point#	Time	Lat	Lon	IRT(°C)				Soil Temp(°C)			Theta Probe (%)			GSM Can ID
				SG	EG	SV	EV	1cm	5cm	10cm	A	B	C	
1	9:00			22	24	22	21	24	23	20	13.3	18.5	15.4	
2	9:05			22	24	22	21	24	23	20	13.3	18.5	15.4	S
3	9:10			22	24	22	21	24	23	20	13.3	18.5	15.4	
4														
5														
6														
7														
8														
9														
10														

SG=Shaded Ground; EG=Exposed Ground; SV=Shaded Vegetation; EV= Exposed Vegetation;

4.3 Theta Probe Soil Moisture Sampling and Processing

The theta probes used were Type ML2 manually-operated impedance instruments manufactured by Delta-T Devices, Ltd. The theta probes have 4 separate 6-cm stainless steel rods that were inserted vertically into the soil. Each instrument was connected to a handheld reader, which delivers the electrical pulse, detects the return signal, and converts the period to voltage between 0 and about 1 V. Site specific calibration for each field of sampling will be performed for theta probe. Theta probe voltage readings from a sampling point were compared to the volumetric soil moisture measured at the same point. A regression relationship was developed and new VSM values were estimated.

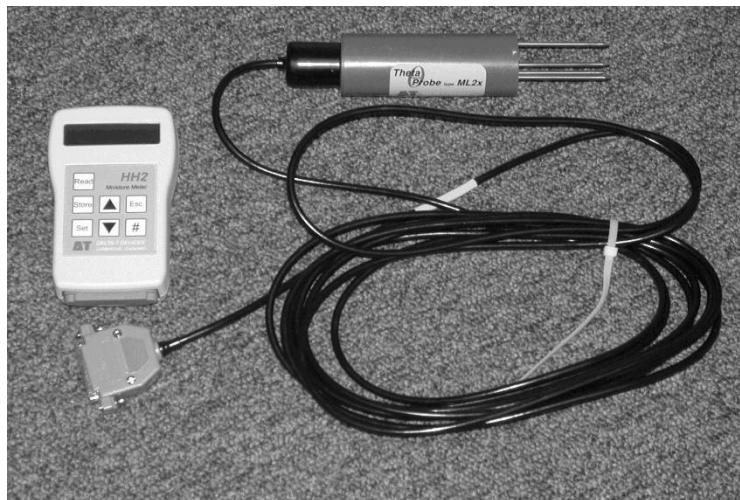


Figure 8. Theta Probe (Handheld).

Each unit consists of the probe (ML2x) and the data logger or moisture meter (HH2). The HH2 reads and stores measurements taken with the ThetaProbe (TP) ML2x soil moisture sensors. It can provide milliVolt readings (mV), soil water (m³.m⁻³), and other measurements. Readings are saved with the time and date of the reading for later collection from a PC.

The HH2 is shown in Figure 9. It applies power to the TP and measures the output signal voltage returned. This can be displayed directly, in mV, or converted into other units. It can convert the mV reading into soil moisture units using conversion tables and soil-specific parameters. Tables are installed for Organic and Mineral soils, however, greater accuracy is possible by developing site-specific parameters by calibration. For this campaign, all observations will be recorded as mV and processed later to soil moisture.

Use of the TP is very simple - you just push the probe into the soil until the rods are fully covered, then using the HH2 obtain a reading. Some general items on using the probe are:

- One person will be the TP coordinator. If you have problems see that person.
- A copy of the manual for the TP and the HH2 will be available at the field HQ. They are also available online as pdf files at <http://www.dynamax.com/#6>, <http://www.delta-t.co.uk> and <http://www.mluri.sari.ac.uk/thetaprobe/tprobe.pdf>.
- Each TP will have an ID, use the same TP in the same sites each day.
- The measurement is made in the region of the four rods.
- Rods should be straight.
- Rods can be replaced.
- Rods should be clean.
- Be careful of stones or objects that may bend the rods.
- Some types of soils can get very hard as they dry. If you encounter a great deal of resistance, stop using the TP in these fields. Supplemental GSM sampling will be used.
- Check that the date and time are correct and that Plot and Sample numbers have been reset from the previous day.
- Disconnect sensor if you see the low battery warning message.
- Protect the HH2 from heavy rain or immersion.
- The TP is sensitive to the water content of the soil sample held within its array of 4 stainless steel rods, but this sensitivity is biased towards the central rod and falls off towards the outside of this cylindrical sampling volume. The presence of air pockets around the rods, particularly around the central rod, will reduce the value of soil moisture content measured.
- Do not remove the TP from soil by pulling on the cable.
- Do not attempt to straighten the measurement rods while they are still attached to the probe body. Even a small degree of bending in the rods (>1mm out of parallel), although not enough to affect the inherent TP accuracy, will increase the likelihood of air pockets around the rods during insertion, and so should be avoided. See the TP coordinator for replacement.



Figure 9. HH2 display.

Before Taking Readings for the Day Check and configure the HH2 settings

1. Press **Esc** to wake the *HH2*.

Check Battery Status

2. Press **Set** to display the **Options** menu
3. Scroll down to **Status** using the **up** and **down** keys and press **Set**.
4. The display will show the following
Mem % Batt %

Readings #.

- If Mem is not 0% see the TP coordinator.
 - If Battery is less than 50% see TP coordinator for replacement. The HH2 can take approximately: 6500 TP readings before needing to replace the battery.
 - If Readings is not 0 see the TP coordinator
5. Press **Esc** to return to the start-up screen.

Check Date and Time

6. Press **Set** to display the **Options** menu
7. Scroll down to **Date and Time** using the **up** and **down** keys and press **Set**.
8. Scroll down to **Date** using the up and down keys and press **Set** to view. It should be in MM/DD/YY format. If incorrect see the TP coordinator or manual.
9. Press **Esc** to return to the start-up screen.
10. Press **Set** to display the **Options** menu
11. Scroll down to **Date and Time** using the **up** and **down** keys and press **Set**.
12. Scroll down to **Time** using the up and down keys and press **Set** to view. It should be local (24 hour) time. If incorrect see the TP coordinator or manual.
13. Press **Esc** to return to the start-up screen.

Set First Plot and Sample ID

14. Press **Set** at the start up screen to display the **Options** Menu.
15. Scroll down to **Data** using the **up** and **down** keys and press **Set**.
16. Select **Plot ID** and press **Set** to display the **Plot ID** options.
17. The default ID should be A. If incorrect scroll through the options, from A to Z, using the **up** and **down** keys, and press **Set** to select one.
18. Press **Esc** to return to the main Options menu.
19. Scroll down to **Data** using the **up** and **down** keys and press **Set**
20. Scroll down to **Sample** and press **Set** to display available options. A sample number is automatically assigned to each reading. It automatically increments by one for each readings stored. You may change the sample number. This can be any number between

- 1 and 2000.
21. The default ID should be 1. If incorrect scroll through the options, using the **up** and **down** keys, and press **Set** to select one.
 22. Press **Esc** to return to the main Options menu.

Select Device ID

23. Each HH2 will have a unique ID between 0 and 255. Press **Set** at the start up or readings screen to display the main **Options** menu.
24. Scroll down to **Data** using the **up** and **down** keys and press **Set**.
25. Select **Device ID** and press **Set** to display the **Device ID** dialog.
26. Your ID will be on the HH2 battery cover.
27. Scroll through the options, from 0 to 255, and press **Set** to select one.
28. Press **Esc** to return to the main menu.

To take Readings

1. Press **Esc** to wake the *HH2*.
2. Press **Read**
If successful the meter displays the reading, e.g.-

ML2 Store?

32.2%vol

3. Press **Store** to save the reading.
The display still shows the measured value as follows:

ML2

32.2%vol

Press **Esc** if you do not want to save the reading. It will still show on the display but has not been saved.

ML2

32.2%vol

4. Press **Read** to take the next reading or change the optional meter settings first. such as the Plot ID. Version 1 of the Moisture Meter can store up to 863 if two sets of units are selected.

Troubleshooting

Changing the Battery

- The HH2 unit works from a single **9 V PP3** type battery. When the battery reaches 6.6V, (~25%) the HH2 displays :
 ***Please Change**

Battery

- On receiving the above warning have your data uploaded to the PC next, or replace the battery. Observe the following warnings:
 - **WARNING 1: Disconnect the TP, immediately on receiving this low battery warning. Failure to heed this warning could result in loss of data.**
 - **WARNING 2: Allow HH2 to sleep before changing battery.**
 - **WARNING 3: Once the battery is disconnected you have 30 seconds to replace it before all stored readings are lost.** If you do not like this prospect, be reassured that your readings are safe indefinitely, (provided that you do disconnect your sensor and you do not disconnect your battery). The meter will, when starting up after a battery change always check the state of its memory and will attempt to recover any readings held. So even if the meter has been without power for more than 30 seconds, the meter may still be able to retain any readings stored.

Display is Blank

The meter will sleep when not used for more than 30 seconds. This means the display will go blank.

- First check that the meter is not sleeping by pressing the Esc key. The display should become visible instantly.
- If the display remains blank, then try all the keys in case one key is faulty.
- Try replacing the battery.
- If you are in bright light, then the display may be obscured by the light shining on the display. Try to move to a darker area or shade the display.

Incorrect Readings being obtained

- Check the device is connected to the meter correctly.
- Has the meter been set up with the correct device.

Zero Readings being obtained

- If the soil moisture value is always reading zero, then an additional test to those in the previous section is to check the battery.

Settings Corrupt Error Message

- The configurations such as sensor type, soil parameters, etc. have been found to be corrupt and are lost. This could be caused by electrical interference, ionizing radiation, a low battery or a software error.

Memory Failure Error Message

- The unit has failed a self-test when powering itself on. The Unit's memory has failed a self test, and is faulty. Stop using and return to HQ.

Some Readings Corrupt Error Message

- Some of the stored readings in memory have been found to be corrupt and are lost. Stop using and return to HQ.

Known Problems

- When setting the date and time, an error occurs if the user fails to respond to the time and date dialog within the period the unit takes to return to itself off. (The solution is to always respond before the unit times out and returns to sleep).
- The Unit takes a reading but fails to allow the user to store it. (This can be caused if due to electrical noise, or if calibrations or configurations have become corrupted. An error message will have been displayed at the point this occurred).

4.4 Gravimetric Soil Moisture Sampling with the Scoop/Spatula Tool

At the specific sampling points:

- Remove vegetation, litter/roots and top soil (0~1cm).
- Use the large spatula (6 cm) to cut four vertical faces at least 6 cm deep.
- Use the small spatula and large spatula to get the soil sample.
- Place each sample in a separate can, the small spatula aids extraction.
- Record these can letter/number in the datasheet at the point location on the map.
- Using electrical tape to seal the can at least for two rounds.
- Place can into a freezer bag and place it back into the tool box.

4.5 Gravimetric Soil Moisture Sample Processing

All GSM samples are processed to obtain a wet and dry weight. Each team will transport the samples to soil lab at Hudson 010 at Duke University. Then the electrical tape will be removed from can, and wet weight will be obtained. The soil sample then will be placed into oven. These samples will remain in the ovens until the morning of the second day (approximately 24 hours).

Wet Weight Procedure

1. Turn on balance.
2. Tare.
3. Obtain wet weight to two decimal places and record on sheet.
4. Process your samples in sample numeric order.
5. Place the CLOSED cans back in the box. Arrange them sequentially.
6. Place box and sheet in assigned locations.

Dry Weight Procedure

1. Each day obtain a balance reference weight on the wet weight balance and the dry weight balance.
2. Pick up all samples from soil lab.
3. Turn off oven and remove samples for a single data sheet and place on tray.
4. These samples will be hot. Wear the gloves provided
5. Turn on balance.
6. Tare.
7. Obtain dry weight to two decimal places and record on sheet.
8. Process your samples in sample numeric order.
9. All samples should remain in the oven for approximately 20-22 hours at 105°C.
10. Try to remove samples in the order they were put in.
11. Load new samples into oven.
12. Turn oven on.
13. Clean all cans that were removed from the ovens and place empty cans in boxes. Check that can numbers are readable and replace any damaged or lost cans with spares.

Drying Ovens

The temperature used for the soil drying ovens is 105oC (for 24hr). Touching the metal sample cans or the inside of the oven may result in burns. Use the safety gloves provided when placing cans in or removing cans from a hot oven. Vegetation drying is conducted at lower temperatures (30oC for 1 week) that pose no hazard.

4.6 Soil Temperature Probes

Several different types of temperature probes may be used to measure soil temperature. These all have a metal rod, plastic top and digital readout. The version used will be the Max/Min Waterproof Digital Thermometer (Figure 10).

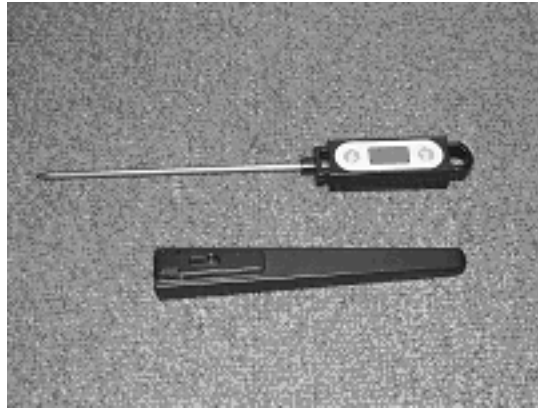


Figure 10. Temperature Probe with Handle/Cover

To Operate:

1. Press On/Off to switch on
2. Verify that the measurement is in Celsius and that the probe is not set to Max or Min
3. Probed into 1 cm of soil at the desired location.
4. Wait for reading to stabilize (might be couple of minutes), and then record the number in the data sheet.
5. Push the probe to a depth of 5 cm, let it stabilize (might be couple of minutes) and record data.
6. Push Probe to a depth of 10 cm, let it stabilize (might be couple of minutes) and record data.
7. Turn off probe and cover.

If necessary the cover can be placed on the top of the probe and used as a handle, but do not force the probe into the ground with undue force, as the probe may break.

Normal operation of the probe is simple, but please make sure that neither Max nor Min appear on the LCD. This is a different mode of operation and will not be used for this experiment.

4.7 Infrared Surface Temperature (IRT)

The infrared surface temperature probe uses 4 AAA batteries that last for a long time.

Operating instructions:

- 1 Press the Red On/Off button
- 2 Verify that the measurement is in Celsius and that the probe is not set to Max or Min. If the probe is set to Max/Min, the LCD display will read Max/Min on the bottom right corner.
- 3 The infrared probe takes an instantaneous measurement (1-2 sec), when you press the red button. The reading will remain on the display after you release the button, till you turn off the device.
- 4 Point the probe on the exposed canopy (making sure your shadow does not fall on the location where you are pointing the probe). Try to take a measurement at the top of the canopy. This may not be possible for sites that have tall corn canopy and for the forest sites. If possible, take a measurement of the exposed vegetation surface as high as possible at these locations. This is surface temperature measurement for exposed vegetation (EG).
- 5 Point the probe on the shaded canopy. Try to make a measurement at roughly half the canopy height. This is surface temperature measurement for shaded vegetation (SG).
- 6 Point the probe on the exposed ground surface (making sure your shadow does not fall on the location where you are pointing the probe). This may not be possible in dense canopy where the vegetation cover is 100% (make a note in the data sheet). This is surface temperature measurement for exposed ground (EG).
- 7 Point the probe on the shaded ground surface. This may not be possible for points which have very little vegetation. This is surface temperature measurement for shaded ground (SG).
- 8 Turn the probe off by holding on the Red button till the LCD display turns off.



Figure 11. Infrared Temperature probe (IRT)

4.8 Soil Bulk Density Sampling with the Coring Tool

All sites involved in gravimetric soil moisture sampling will be characterized for soil bulk density. The method used is a volume extraction technique that has been employed in most of the previous experiments and is especially appropriate for the surface layer. Four replications are made for each site.

- The tool is called a 200-A soil core sampler.
- Figure 12 shows the parts of the apparatus.
- The thin cutting tip will be used because we anticipate that the soils will be uniform and rock-free. This can be replaced using a spanner tool to unscrew it from the barrel.
- The cap is unscrewed to insert or remove rings.
- The ring volumes are $1 \text{ cm} = x \text{ cm}^3$ and $5 \text{ cm} = y \text{ cm}^3$.

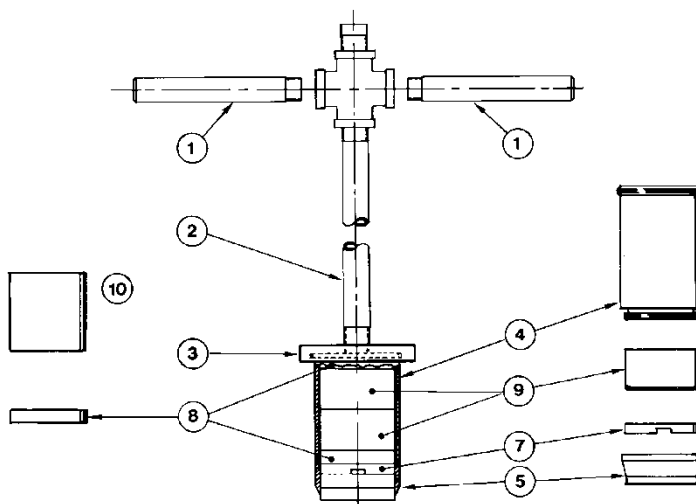
Procedure for Taking a Sample

- Insert three sample rings and the extractor ring in the following order starting from the cutting end
 - Extractor
 - 2 cm
 - 5 cm
 - 1 cm
- Replace cap with handle
- Insert the coring tool into the soil. If necessary, the hammer tool can be used. The hammer rod is inserted into the handle.
- Stop when the lip of the cap reaches the surface, try not to compact the sample.
- Remove the core and inspect the tip to make sure the notches on the extractor ring are clear. Use the extractor tool (Figure 12) to assist in cleaning these notches. Also inspect for separation within the coring tool by looking for protruding soil at the bottom of the tool. If there is separation, dispose of this sample and start again.
- Remove the cap.
- Use the extractor tool (from the bottom or cutting edge) to push the rings out the top or cap end.
- Using a wide spatula, cut the rings apart into the soil moisture cans using the soil funnel to insure capture of the entire sample..
- Place the 1 cm and 5 cm samples in cans (Remember odd-1 cm and even-5 cm).
- It can be difficult to extract a perfect surface 1 cm sample for bulk density. However, it is still useful as a GSM sample. Please make a note on the sample quality in your notebook.
- Clean all rings.

Computing the Volumetric Soil Moisture and Bulk Density

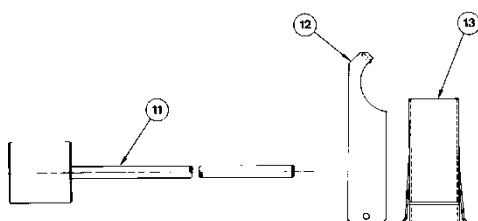
- Compute the sample GSM and dry mass
- Divide the mass of the soil by the volume of the cylinder (1 or 5 cm) hole to obtain the sample bulk density
- Compute $VSM = GSM * BD$

MODEL 200 SOIL CORE SAMPLER AUGUST 1989



PARTS BREAKDOWN

ITEM NO.	PART NO.	DESCRIPTION	ITEM NO.	PART NO.	DESCRIPTION
1	201-6	HANDLE	7	201-9	NOTCHED EXTRACTOR RING
2	201-100	STEM ASSEMBLY	8	208	CYLINDER 1 CM. LONG
3	201-4	CAP	9	207	CYLINDER 3 CM. LONG
4	201-3	BARREL	10	206	CYLINDER 6 CM. LONG
5	201-1	BLADE CORING TIP			



PARTS BREAKDOWN (CONTINUED)

ITEM NO.	PART NO.	DESCRIPTION
11	202	DRIVE HAMMER
12	203	SPANNER WRENCH
13	204	NOTCHED CORE EXTRACTOR

Figure 12. Coring tool parts.

4.9 Surface Roughness

Vegetation will interfere with the collection of the roughness. Thus vegetation in front of the board will be removed carefully (or flattened by using a long piece of cardboard).

It is important to characterize roughness in the same direction as the look direction of the radar instruments, particularly if any macrostructure is present. Consequently the roughness profiles need to be taken parallel to the look directions of the flights.

- Take a photo along and across the rows at each bulk density location with the grid board.
- The site and sample ID should be indicated in the photo.
-



4.10 Vegetation Sampling

Purpose of Sampling

The purpose of vegetative sampling is to provide an estimate of the variation in the vegetative components in the corn and soybean fields across the SMEX02 study sites.

Parameters

1. Plant height
2. Ground cover
3. Stand density
4. Phenology
5. Leaf area
6. Green and dry biomass

Sampling Locations

Three sites within each field will be sampled during the course of the study to quantify the full range of vegetative cover. A minimum of three sampling times will be considered for SMEX02, a week before the study during the first week, and during the last week. Sites will be determined through aerial surveys of the sampling fields conducted during an early May and early June overflight. This is necessary since the spatial pattern across the field will depend upon the soil water distribution. For example, in the case of a wet spring the soils in the potholes of the landscape will be water stressed because of excess water and growth will be slowed, conversely in a dry year growth may be enhanced in the lower areas because of the increased soil water availability.

Site Identification

Sites will be identified with a unique site id made of the field number, within field site and row number, e.g., field number = V09 plus site 1 plus row 2 yields an id of V0912. The V will denote a vegetative sampling site to avoid any potential confusion with other measurement sites within the same field.

Sampling Layout

Each site will be identified with a flag in the right hand corner and a pole that extends above the crop height to aid in locating the site. Each sampling site will consist of a 10 row area by 10 m. This will provide adequate area for all sampling dates (see Figure 13).

Sites will be located with GPS units and coordinates recorded for the corners of the site prior to the first sample collection. Sampling will not require the use of GPS but the right hand row of the sampling site will be flagged at the end row of the field so the sampling crews can travel down the rows.

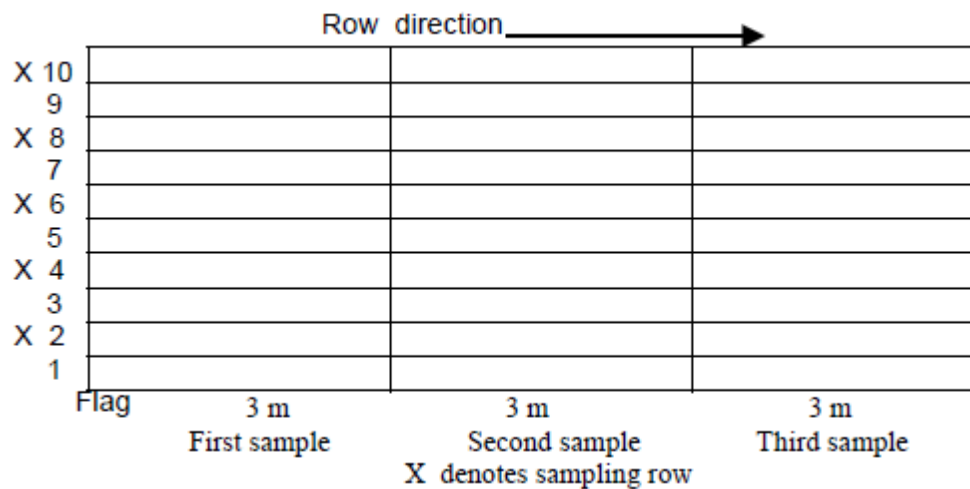


Figure 13. Vegetation sampling layout.

Sampling Scheme

Sampling sites are designed to provide a representative sample from the area of the field. One plant will be sampled from every other row for phenological stage and green and dry biomass (5 plants total). These same rows will be sampled for height, stand density, and row cover. Leaf area will be measured at four locations (in-row, $\frac{1}{4}$ across row, $\frac{1}{2}$ across row, $\frac{3}{4}$ across row) with LI-2000. The first sampling position will be between the first row (flag location and the row to the left).

The first sampling time will begin on the end next to the flag, the second sampling time will begin 3 m down the row from the flag, and the third 6 m from the flag.

Protocols

1. Stand density

Stand density will be determined by placing meter stick along the row in each of the 5 rows sampled. The meter stick will be placed at the center of a plant stem and that stem counted as the first plant. All plants within the one-meter length are to be counted. If a plant is at the end of the meter stick and more than half of the stalk extends beyond the end of the meter stick it is not counted. Counts are recorded onto the sampling sheet.

2. Phenology

Phenological stage for corn and soybean will be determined using the standard phenological guide. The guide is attached as an appendix to this protocol. Plants from the sampling rows will be measured and recorded.

3. Height

Height will be measured by placing a measuring rod on the soil surface in the row and recording the height of the foliage using a horizontal bar that just touches the upper leaves. One person will hold the measuring stick and the other determine the proper position of the horizontal bar.

4. Green and Dry Biomass

To measure biomass a plant will be cut at the ground surface from each sampling row. The five plants for the sampling site will be placed into a plastic bag with a label for the sampling site. A separate tag with the sampling site id will be placed into the bag as additional insurance against damaged labels. These plants will be transported to the field facility for separation of the plant material into stalks and leaves for corn and stems and leaves for soybean. Corn plants can be separated into leaves and stalks in the field for easier transport to the laboratory. These plant parts will be placed into a bag for drying and marked with sample site id.

Green biomass will be measured for both components (stalks or stems and leaves) by weighing the sample immediately after separation of the components. If the biomass has excess of moisture on the leaves and stalks this will be removed by blotting with a paper towel prior to weighing. Dry biomass will be determined after drying the plant components in ovens at 75C for 48 hours.

5. Photographs

Photographs will be taken of plot area at the time of sampling. These will be collected with a digital camera. A marker board will be used to mark the plot, field location, and date. Photographs will be collected at an oblique angle (30-45° from horizontal) and at nadir at a height of a minimum of 1 m above the canopy. Cameras will be fixed to a telescoping pole to allow positioning above the canopy and a remote trigger to collect data. Three photos will be taken in each plot in this order; marker board, oblique, and nadir.

Data Recording

Data will be recorded onto the sampling sheet illustrated in Figure 14. Each field will have a separate notebook and data sheets for each sampling plot within the field. Each blank on the sheet will be filled in during the observation period. Data sheets will be maintained as part of the permanent experimental record to verify the data once it is entered into the computer.

Vegetative Sampling Date _____ Observers _____

Time _____

Row Spacing _____

Row Direction _____

Crop _____

Photographs Taken _____

	Stand density	Height	Phenology	Ground Cover	Green (g) Biomass	Dry (g) Biomass	Leaf	Sun/shade

Sample id									Area Index	
	(plants/m)	(m)		(%)	Stem	Leaf	Stem	Leaf		
V10102					x	x	x	x		
V10104					x	x	x	x		
V10106					x	x	x	x		
V10108					x	x	x	x		
V10110										

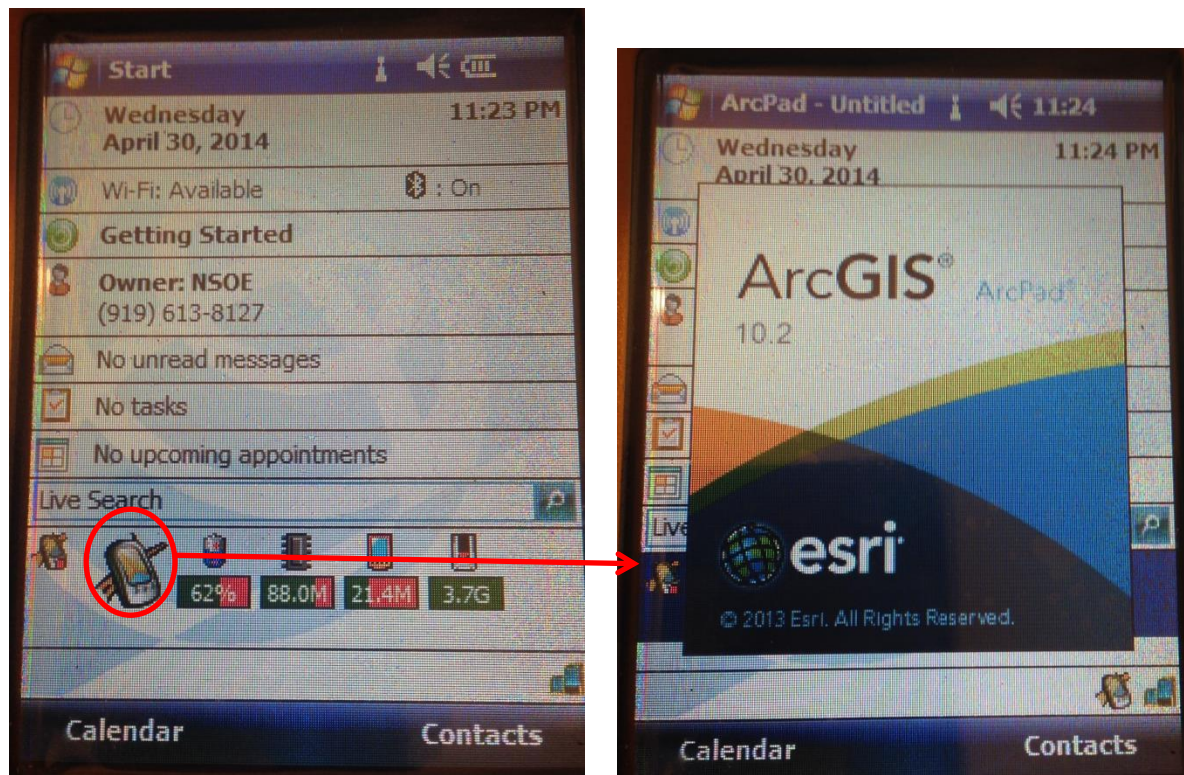
Figure 14. Example of the vegetation sampling data sheet.

4.11 Global Positioning System (GPS) Coordinates

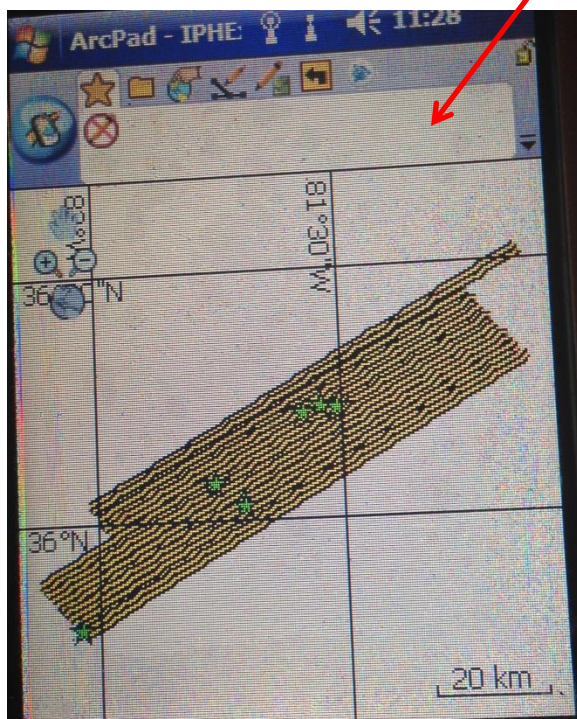
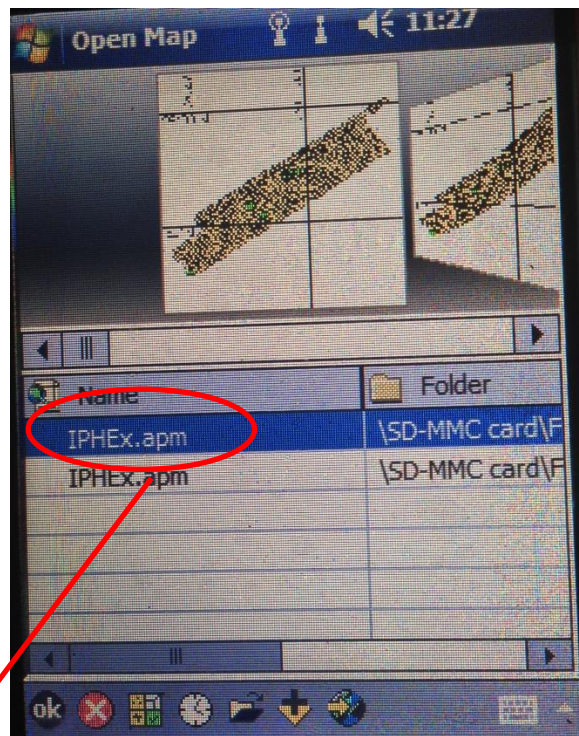
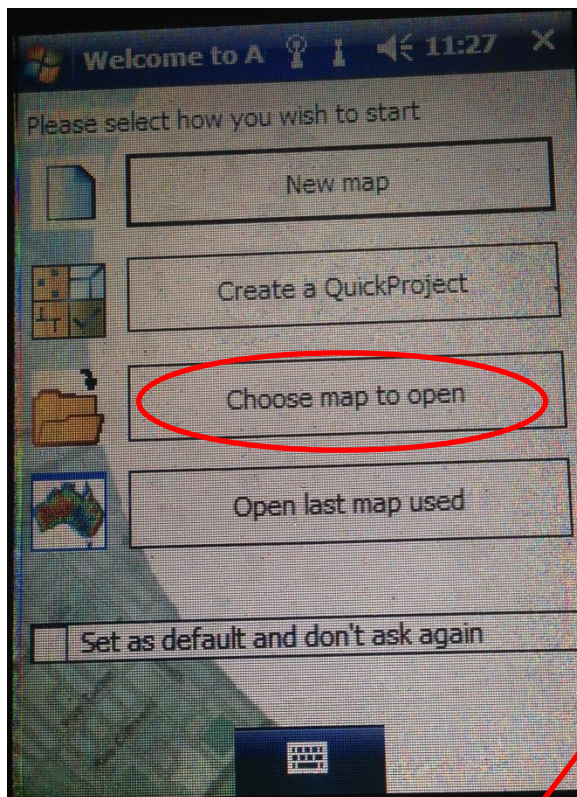
The acquisition of geographic coordinates at all sample point locations are necessary for mapping of data in a Geographic Information System (GIS). A Trimble Juno's GPS will be used to collect location data, it uses ArcPad/Trimble GPSCorrect as the software interface.

Steps:

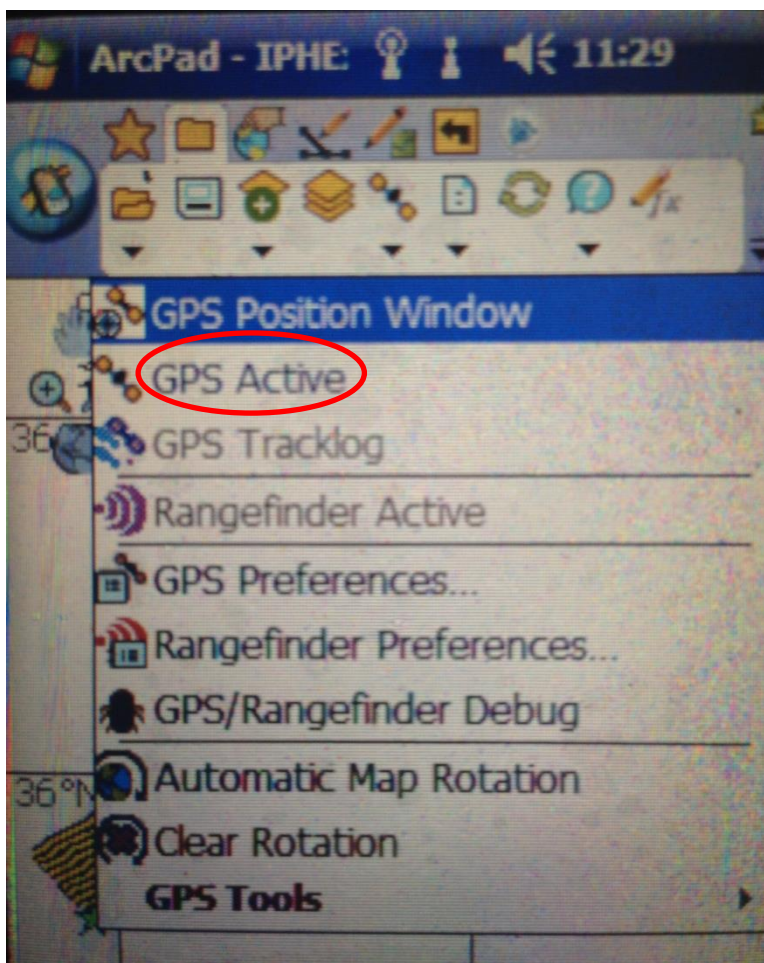
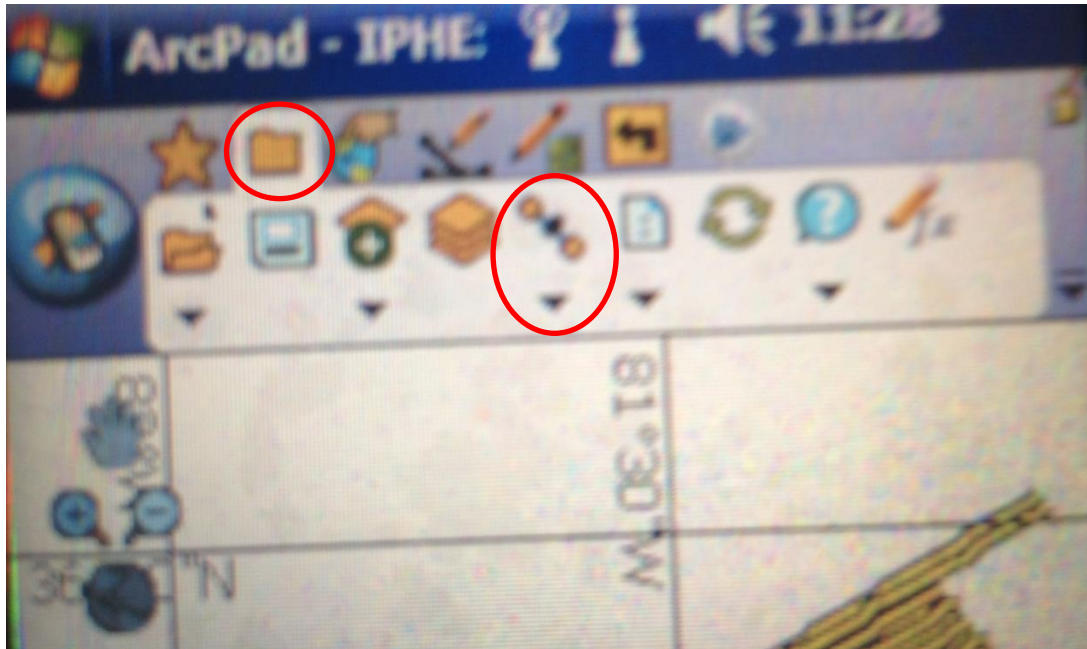
1. Open, click the software



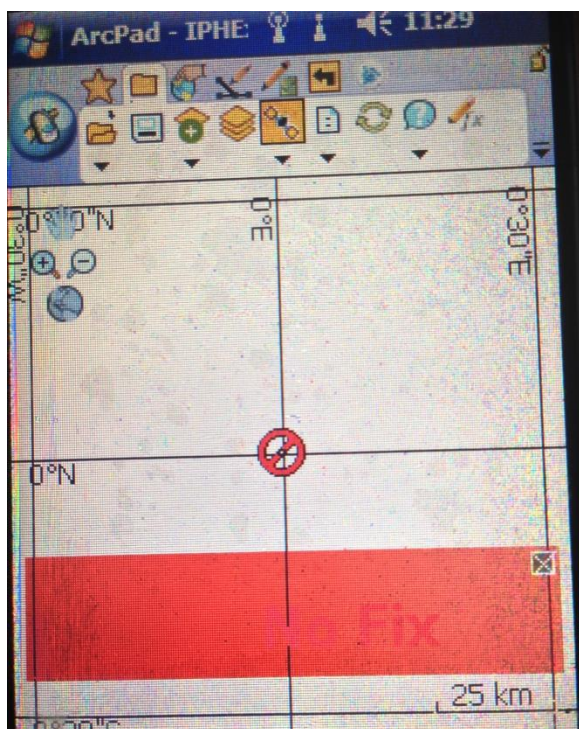
2. Choose map to open, then choose IPHEX project



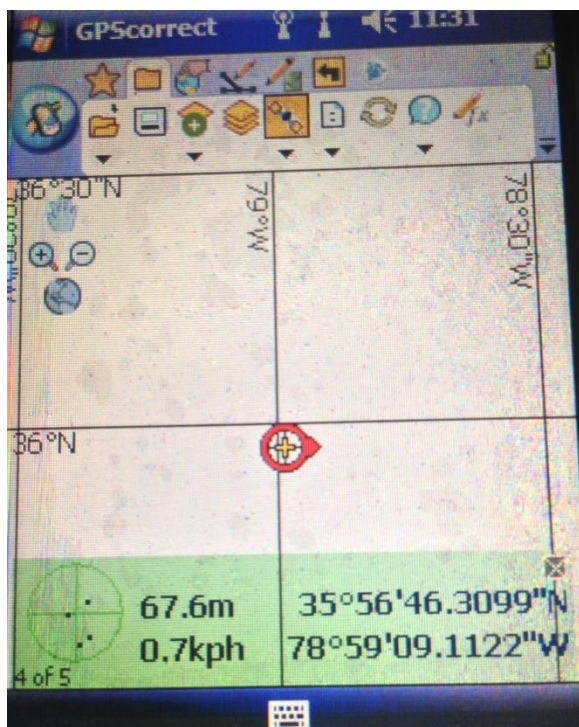
3. Active GPS:



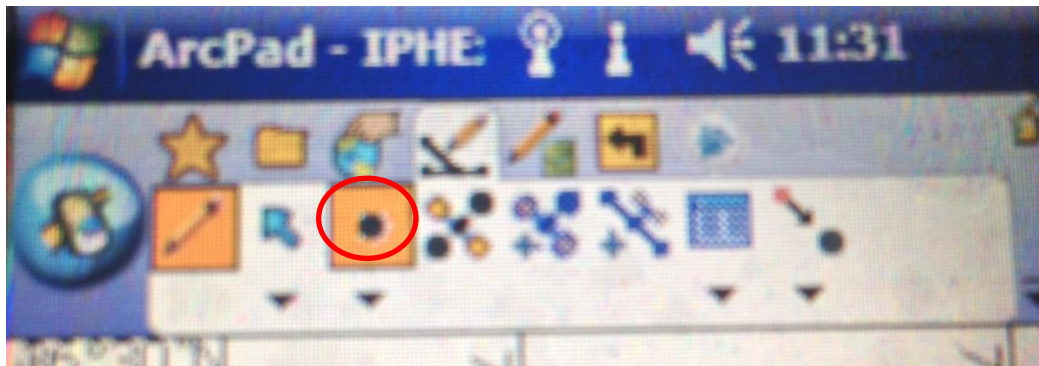
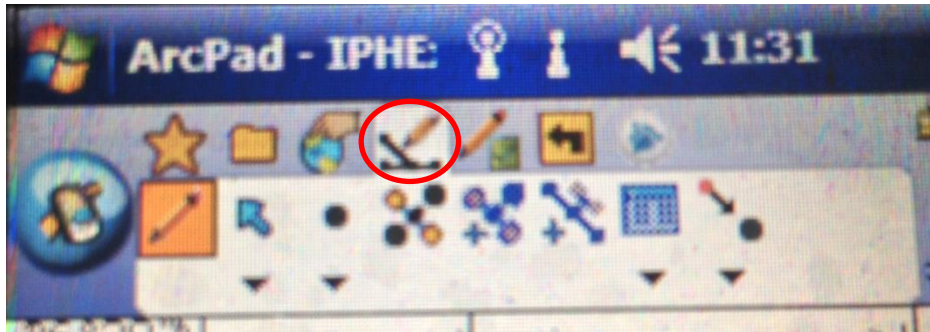
Before it can find any satellite signal, the bottom shows red color



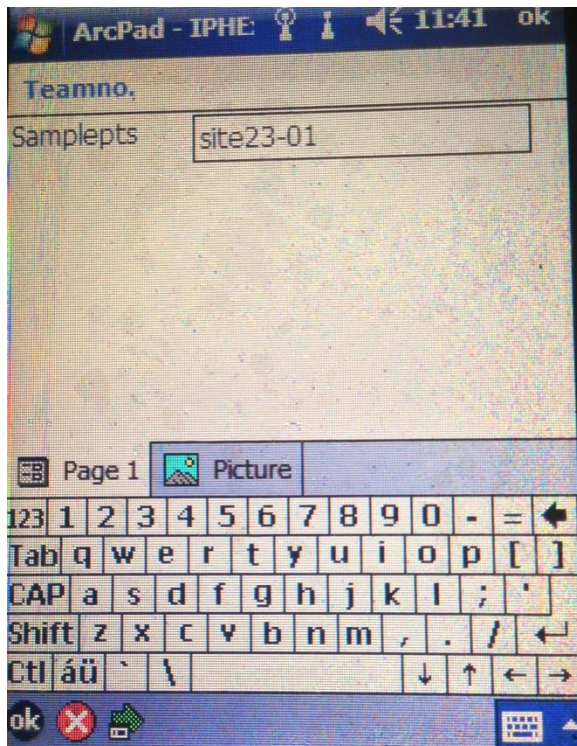
Wait for a while, it will find satellites and show the lat&long data.



4. Save the point:



Click on the screen, then type the site number and point number



After you finish sampling, remember to save the map, and then exit.

5. Schedule

Approximate flight date	About 2~3 days ago
Initial Inform about the flight (phone call/message or email)	3:30pm on Previous day
Get cars and departure from Durham to hotel in Boone	5pm
Final Inform about the flight (phone call/message or email)	7am the next morning (flight date)
Get equipment box from group leader and leave for sampling	Depending on sites 8am~9am
Arrival at site and conduct sampling (2~3 fields per team)	~9:30am
End of sampling, return the equipment box to group leader	~11:30am
Drive back to Durham and return cars	5pm
Activities after back to Duke (dry soil samples)	flexible

6. Logistics

Hotel: (Three rooms were reserved by Dianne Bennett <dbennett@duke.edu>)

Sleep Inn(NC514)

163 Hwy 105 Extension, Boone, NC, US, 28607

Phone: [\(828\) 262-0020](tel:(828)262-0020)

Comfort Suites(NC052)

1184 SR 105,

Boone, NC, US, 28607

Phone: [\(828\) 268-0099](tel:(828)268-0099)

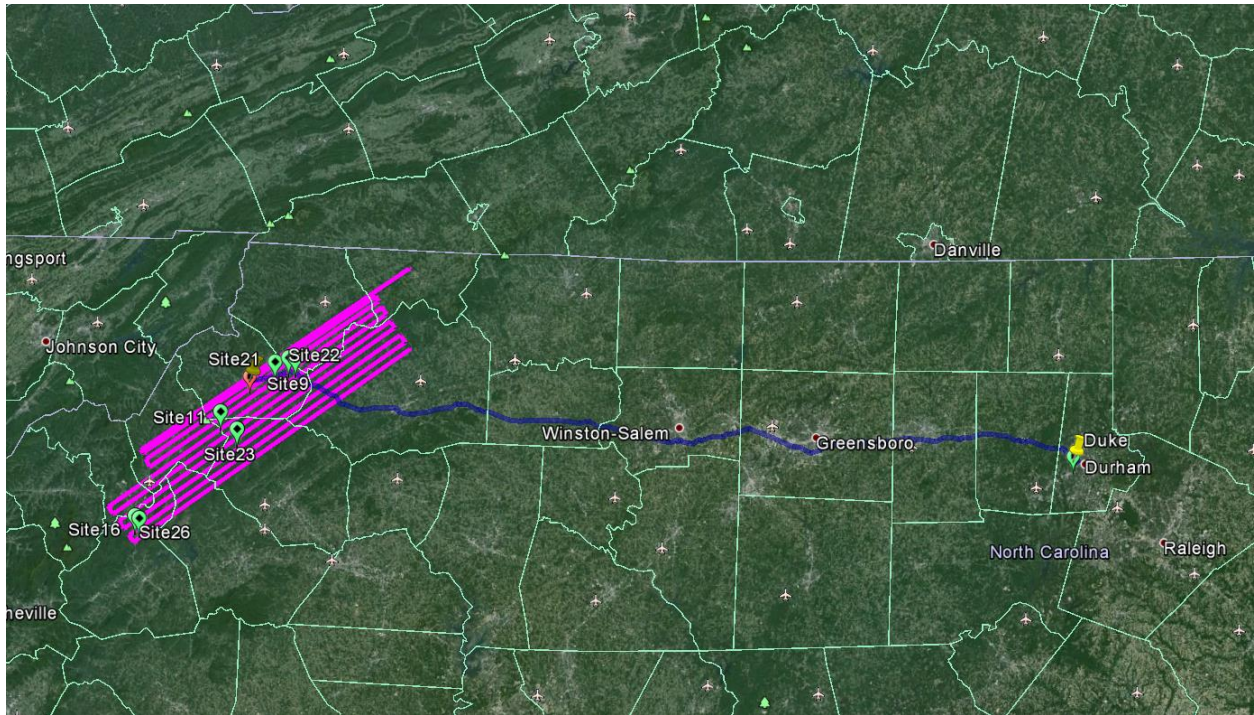
Cars: (Three cars were reserved by Dianne Bennett <dbennett@duke.edu>)

Enterprise Rent-A-Car

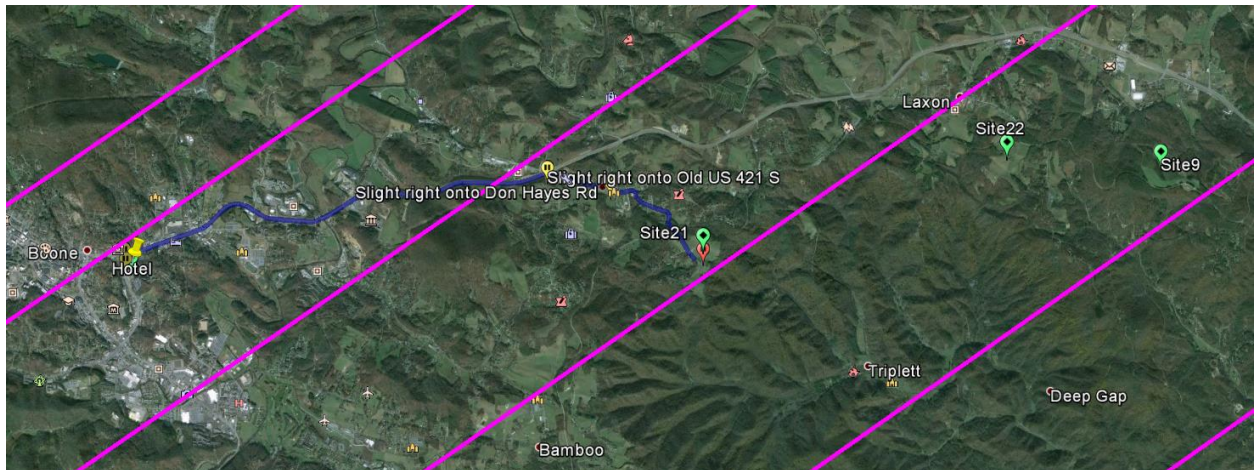
3143 Hillsborough Rd, Durham, NC 27705

[\(919\) 309-1030](tel:(919)309-1030)

Directions:



Group1



Hotel

NC-105
Extension/US-
221 N

**1. Head north on NC-105 Extension/US-
221 N toward E King St**

413 ft

**2. Take the 1st right onto US-421 S/E King
St**

Continue to follow US-421 S

3.7
mi

3. Slight right onto **Old US 421 S**

0.5
mi

4. Slight right onto **Don Hayes Rd**

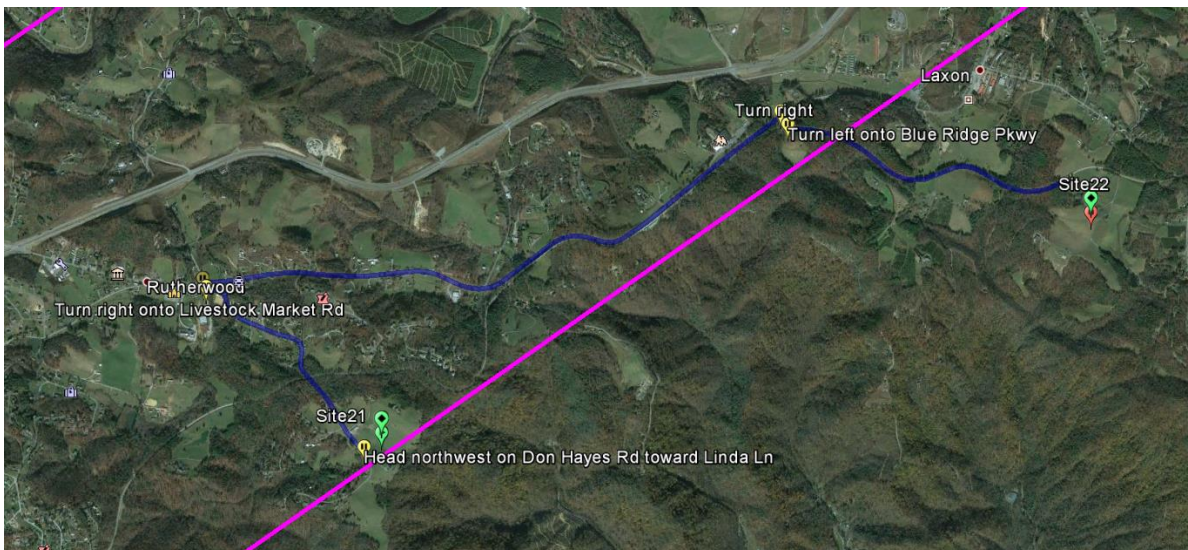
1.0
mi



Site21
Don Hayes Rd



From Site 21 to site 22:



Site21

Don
Hayes
Rd

**1. Head northwest on Don Hayes
Rd toward Linda Ln**

0.9
mi

2. Turn right onto Livestock Market Rd

167 ft

3. Turn right onto Old US 421 S

2.3
mi

4. Turn right toward Blue Ridge Pkwy

302 ft

5. Turn left onto Blue Ridge Pkwy

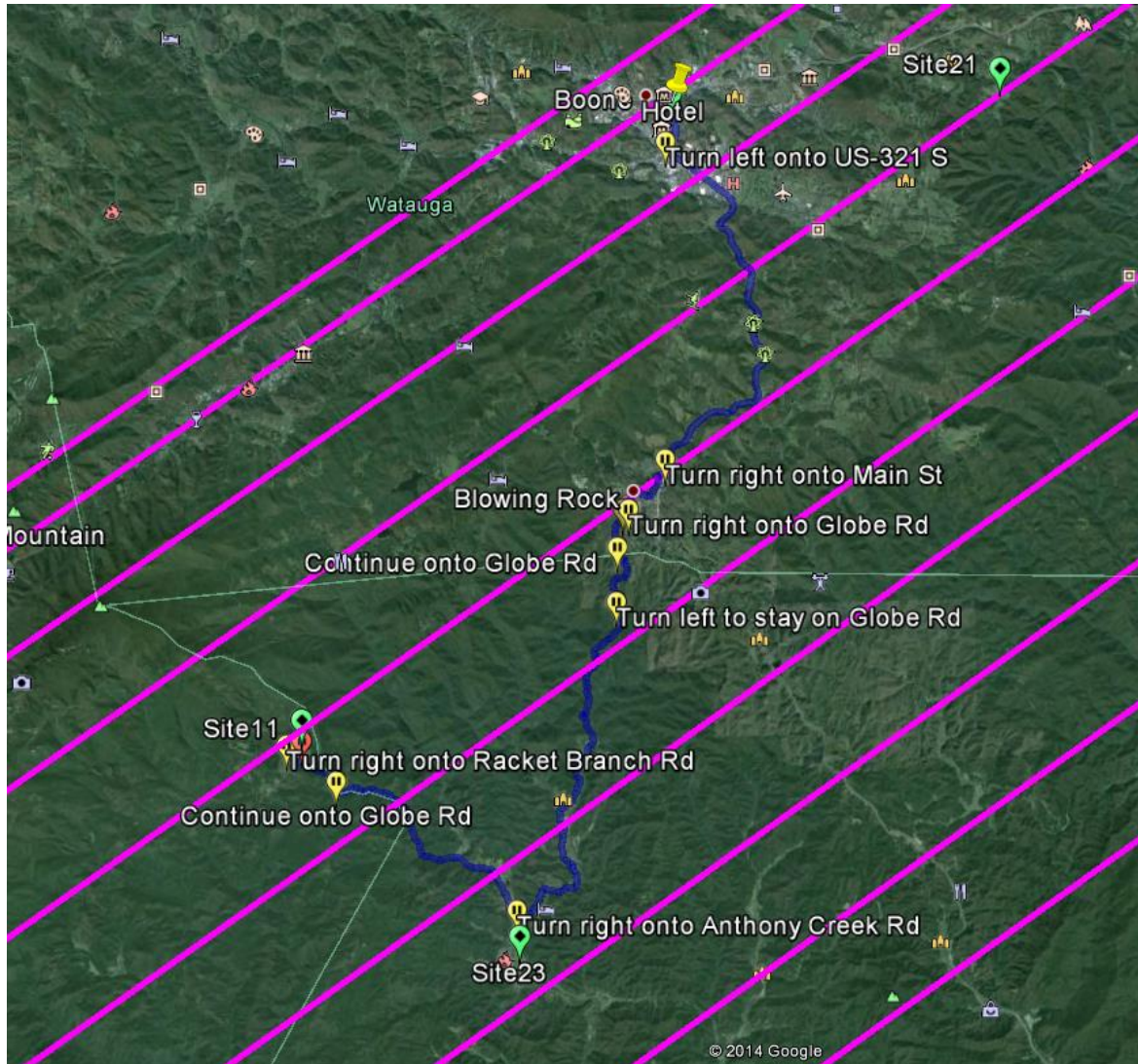
1.1
mi



Site22
Blue Ridge Pkwy



Group2:



Hotel

NC-105

Extension/US-

221 S

1. Head south on NC-105 Extension/US-221 S toward Quail St

0.7
mi

2. Turn left onto US-321 S/Blowing Rock Rd

Continue to follow US-321 S

6.3
mi

3. Turn right onto Main St

- 1.2
mi

4. Turn right onto **Globe Rd**
- 469 ft

5. Continue onto **Johns River Rd**
- 0.6
mi

6. Continue onto **Globe Rd**
- 1.1
mi

7. Turn left to stay on **Globe Rd**
- 6.0
mi

8. Turn right onto **Anthony Creek Rd**
- 3.8
mi

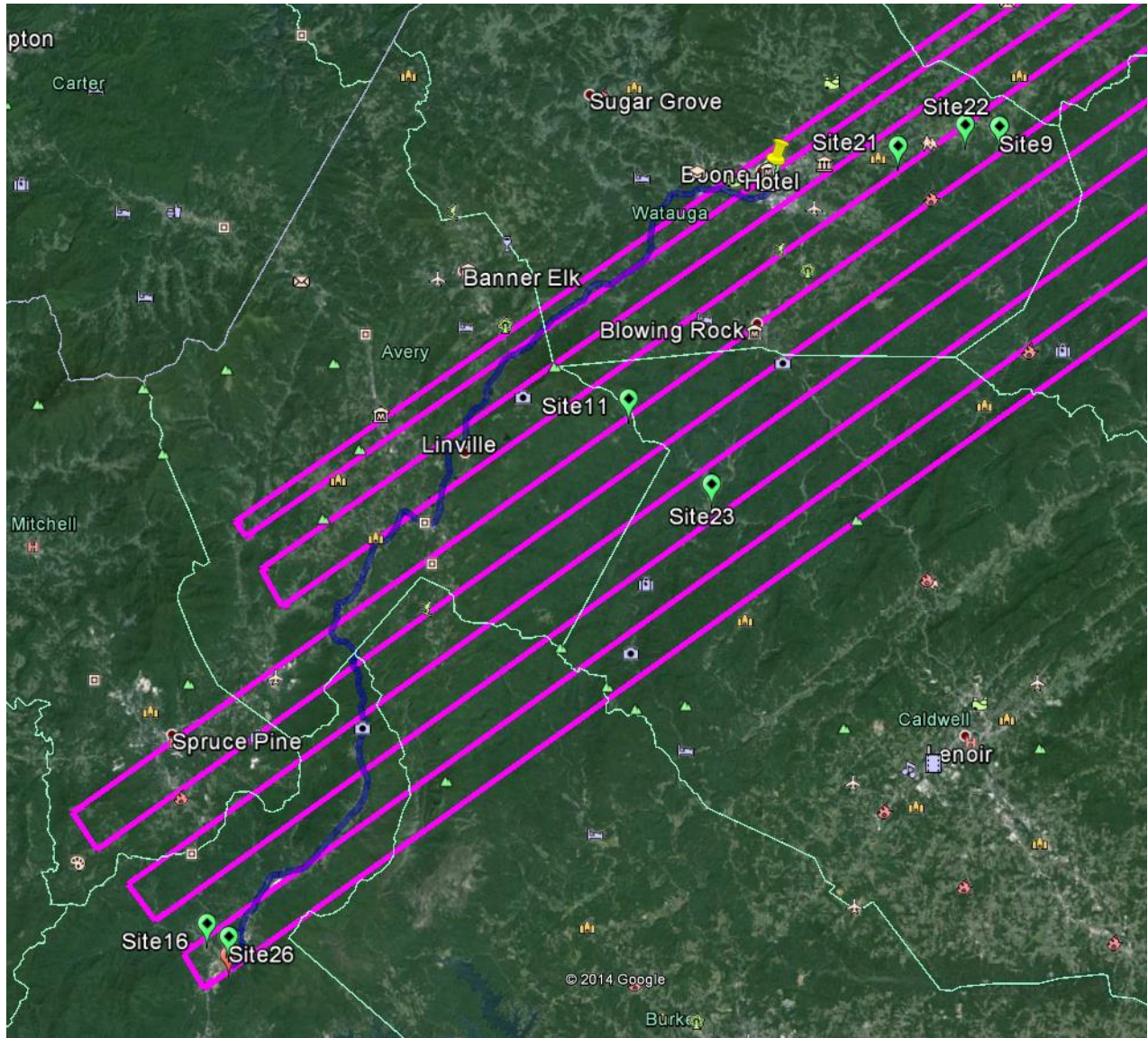
9. Continue onto **Globe Rd**
- 0.9
mi

10. Turn right onto **Racket Branch Rd**
Destination will be on the left
- 0.2
mi



Site11
Racket Branch Rd

Group3



Hotel

NC-105

Extension/US-
221 S

**1. Head south on NC-105 Extension/US-
221 S toward Quail St**

0.7
mi

2. Continue onto NC-105 S

16.9
mi

3. Turn right onto NC-181 N

4. Turn left onto **US-221 BUS S**

0.6
mi

5. Continue onto **NC-181 S/US-221 S**
Continue to follow US-221 S

1.1
mi

6. Turn left onto **American Thread Rd**

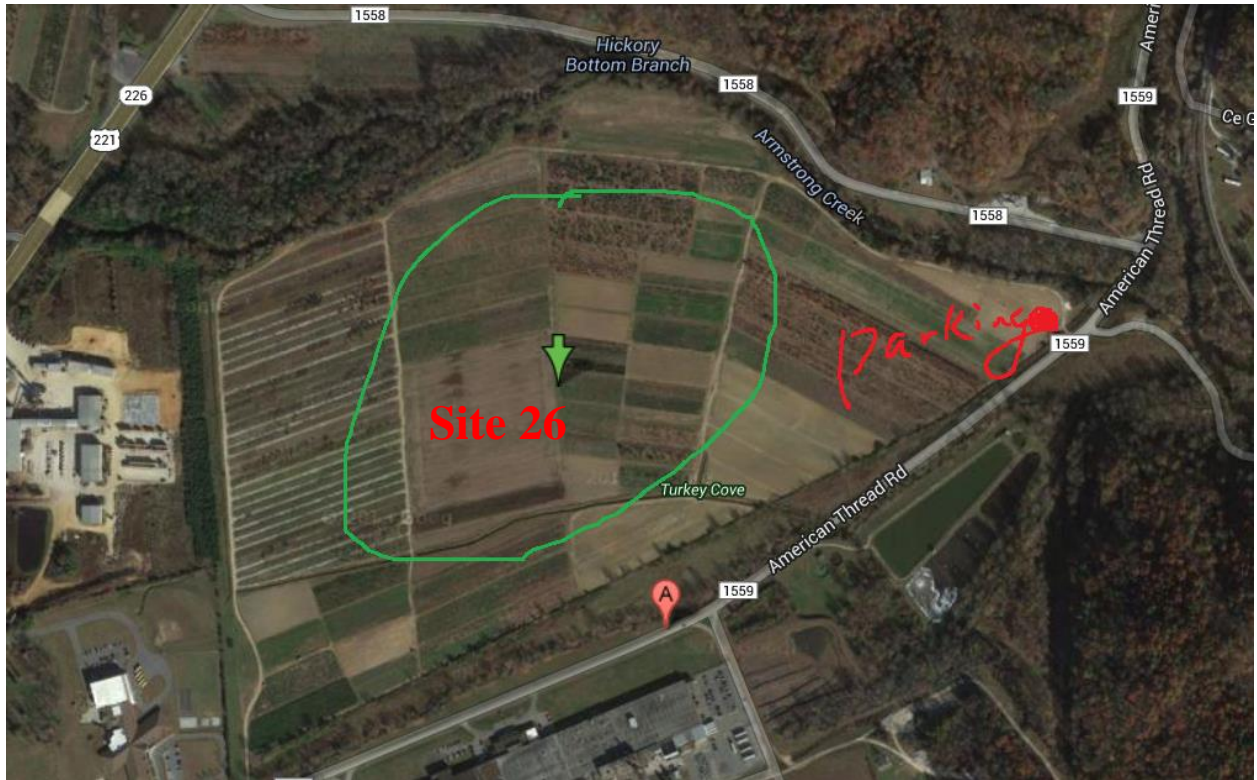
22.9
mi

1.7
mi



Site26
American Thread Rd





7. Volunteer List

Name	Department/Univ.	Intro.	Email	CellPhone
Jing Tao	CEE/Duke	PhD student	jing.tao@duke.edu	919-699-0936
Anna Yang	BME/ECE/Duke	Undergraduate	hy61@duke.edu	919-402-7689
Xiaochi Zhou	CEE/Duke	PhD student	xz84@duke.edu	919-450-8827
Sarah Diringer	CEE/Duke	PhD student	sed31@duke.edu	805-441-7054
Tan Zi	CEE/Duke	PhD student	tz21@duke.edu	919-316-8458
Jun Yin	CEE/Duke	PhD student	jy85@duke.edu	919-561-9958
Winnie Biwott	Trinity	Undergraduate	wjb11@duke.edu	919-641-2585
Wenjie Wang	CEE/Duke	Master student	ww75@duke.edu	919-381-2889
Thu Nguyen	Trinity / Chemistry	Undergraduate	thu.nguyen@duke.edu	919-609-8115
Ke Xue	CEE/Duke	Master student	kx9@duke.edu	919-937-4464
Troy Bass	EEGS/NCCU	Master student	tbass18@eagles.nccu.edu	512-659-5216
Manman Hu	CEE/Duke	PhD student	manman.hu@duke.edu	919-316-9009
Wenjie Lu	MEMS/Duke	PhD student	wenjie.lu@duke.edu	919-627-0048